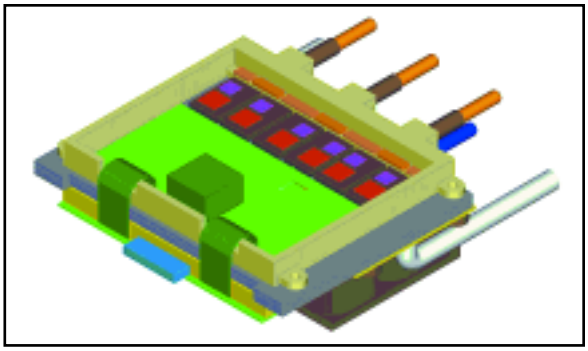
Inverter for traction motor control in HEVs delivers high power density at low cost

OAAT ACCOMPLISHMENTS

Automotive Integrated Power Module

Challenge

Hybrid electric vehicles (HEVs) require a low-cost, compact, lightweight, high-efficiency inverter to power and control the vehicles' AC traction motor. The Automotive Integrated Power Module (AIPM) is specified to deliver a variable frequency ac output of 55 kW peak and 30 kW continuous with control compatible with either induction or permanent magnet traction motors.



Rockwell automation approach: three phase wires in brown; red and blue are for DC input; white tubes are for cooling liquid; and I/O port (light blue) is in front.

While program specifications require a package size limit of 4.58 L, maximum weight of 11kg, and full load efficiency of 97%, the manufacturing cost is of most concern to the Partnership for a New Generation of Vehicles (PNGV) and its Electrical and Electronics (E-E) Tech Team. In quantities of 100,000 pieces/year, the AIPM cost specification is set at $7/kW ($385).

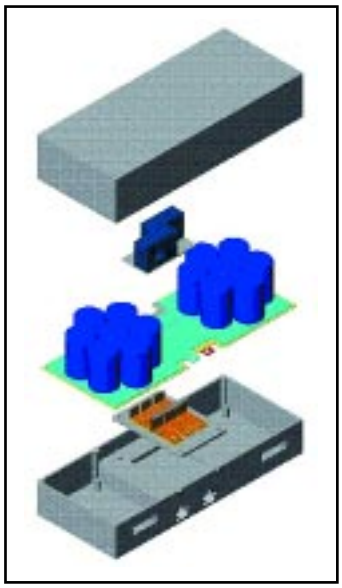
To put this challenge into perspective, the manufacturing cost of today's best industrial motor drives in the 55 kW rating range is $35/kW. It is estimated that development efforts to date within the automotive OEMs have netted traction inverter designs with cost projections of about $17/kW.

Technology Description

A team from Silicon Power Corporation (SPCO), Rockwell Science Center (RSC), and Rockwell Automation (RA) has developed and advanced a number of key technologies and embodied them into parallel concept designs presently being prepared for pre-alpha demonstration and testing in May 2001.

Among those technologies are:

- An IGBT power switch packaged by Silicon Power in their proprietary ThinPak module, about the size of a credit card. The ThinPak module doubles the power output of conventional switch packages. It requires no wire bonds.
- A hybrid IGBT/MCT power switch in a ThinPak module similar to the above. The integrated high-side MCTs (Mos-Controlled Thyristors) are a unique SPCO technology.
- An advanced direct die bonded IGBT power switch developed by Rockwell Automation
- Liquid chill plates featuring copper foam, folded fin and pin-fin technology
- An extremely simple 16-bit DSP controller developed by the Rockwell Science Center
- Alternative bus filter designs utilizing both bulk and distributed film capacitor technology



SPCO approach shows a laminated bus structure for DC and AC power; cylinders in figure are capacitors; while ThinPak (brown) is below.

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- Advanced integrated current sensor designs
- Alternative package and connection designs for minimum EMI/RFI, simplicity and low cost.

Accomplishments

The development team rationalized all program specifications and offered alternatives where appropriate. "Cost sensitivity" analyses were conducted on a number of system and technology issues. The team presented the results of these studies with recommendations to the U.S. Department of Energy and the PNGV E-E/Tech Team on the cost effects of:

- Minimum battery voltage for full output power
- Underhood operating temperatures above 105° C
- Minimum motor inductance below 100 microhenries
- Increasing continuous power rating from 22 to 30 kW.

The team designed and conducted an organized "Technology Gap Analysis." This analysis partitioned AIPM cost by critical technology, determined current technology costs for each, and proposed a path forward to achieve $7/kW. At its inception (summer 2000), the team estimated then-current costs of $17/kW for AIPM. From that point, team members:

- Selected trusted supply partners for each critical technology – 30 suppliers in all
- Conducted four-hour technology roadmap reviews with each
- Explored alternatives and trade-offs
- Built these findings into the parallel pre-alpha design concepts currently in design
- Developed a model for periodic cost review and reporting, providing a tool to assure progress to $7/kW.

The team reported progress to $10.49/kW at the January E-E/Tech Team Program Review.

They presented alternative concept designs currently being prepared for pre-alpha verification and testing.

Benefits

A number of alternative SPCO/Rockwell AIPM designs will offer compact, lightweight, low-loss and very low-cost solutions for PNGV traction motor power and control. Designed for rugged underhood environmental conditions, two designs will be selected and advanced to alpha pre-production status.

Future Activities

Silicon Power and Rockwell plan to commercialize technologies developed within the AIPM program within the industrial and power quality markets in which they are presently involved.

Pre-alpha units will be readied for demonstration and test in May 2001. They will be refined and demonstrated during summer 2001. An SPCO/Rockwell manufacturing team has been commissioned to begin the process of industrialization to address issues of labor, overhead, and manufacturing.

Partners in Success

- Micrel, Inc.
- PNGV E-E/Tech Team
- Selected Supplier Partners
- Rockwell Automation
- Rockwell Science Center
- Silicon Power Corporation